Australian Government
Department of Defence
Defence Science and
Technology Organisation

Exercise Black Skies 2008: Enhancing Live Training Through Virtual Preparation

Part One: An Evaluation of Training Effectiveness

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Air Operations Division
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DSTO-RR-0344

ABSTRACT

This research employed a case study strategy to examine the benefits of using synthetic environments to provide mission preparation for command and control teams prior to a large-scale, live warfighting exercise. During Pitch Black 08, we compared the performance of two Air Battle Management (ABM) teams from 41 Wing, Surveillance and Response Group: one team prepared by supporting normal flying operations, the other took part in a virtual mission preparation exercise named Black Skies 08. The synthetic environment provided in Black Skies 08 was designed to simulate Pitch Black 08 as closely as possible in terms of mission scenarios, order of battle, airspace, procedures, and tactics. The evaluation of the training provided in the virtual mission preparation was carried out using the four-level model developed by Kirkpatrick (1959): Reaction, Learning, Behavioural, and Results critera. The members of the ABM team that participated in Black Skies 08 reported that the virtual mission preparation compared favourably to both regular training and live exercises in terms of the capacity to provide training experiences critical to the ABM role. Over the course of the virtual mission preparation, the ABM team displayed a marked improvement in teamwork processes, motivational state, and across most mission essential tasks. During the subsequent live warfighting exercise, the teamwork processes and taskwork performance of this team were rated as better overall than those of the matched ABM team that did not take part in virtual mission preparation. The virtual mission preparation also demonstrated a broader organisational and operational value to the RAAF: it provided the White Force with the opportunity to identify deficiencies in, and mitigate risks associated with, the Pitch Black mission scenarios; and it allowed the ABM team to refine their Pitch Black plans and procedures, enabling them to more effectively utilise the valuable training opportunity presented by a large-scale, live warfighting exercise.

Published by

Air Operations Division
DSTO Defence Science and Technology Organisation
506 Lorimer St
Fishermans Bend, Victoria 3207 Australia

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AR-014-567
November 2009

APPROVED FOR PUBLIC RELEASE

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Part One: An Evaluation of Training Effectiveness

Executive Summary

The first principle of Australian Defence training doctrine is that our forces should train as they operate (Australian Defence Force Warfare Centre, 2006). For air warfare command and control teams, however, the opportunity to take part in training that faithfully replicates operational environments is rare, largely restricted to participation in exercises such as Pitch Black and Talisman Sabre. The scarcity of these valuable training opportunities has generated considerable interest in the use of synthetic environments as a means of supplementing or augmenting live training. In *The Future Air and Space Operating Concept* (Air Power Development Centre, 2007), virtual and simulated environments are identified as crucial to building appropriate skill sets and experience in Royal Australian Air Force (RAAF) warfighters.

The study described in this report forms part of a collaborative research program between DSTO's Air Operations Division and the US AFRL's Human Effectiveness Directorate, under the auspices of *Project Arrangement PA-AF-0025: Distributed Mission Training Research*. This study had both broad and specific research goals. The broad research goal was to investigate the effectiveness of a range of tools and methods for structuring and managing RAAF synthetic team and collective training. The method and outcomes relating to this broad goal are presented in a companion report (Tracey, Hasenbosch, Vince, Pope, Stott, Best, Shanahan, & Finch, 2009). The specific research goal, and the focus of this report, was to investigate the potential benefits to the RAAF of using synthetic environments to provide virtual mission preparation for live, large scale training exercises.

A case study strategy was employed to examine the benefits of using synthetic environments to provide mission preparation for a 41WG Air Battle Management (ABM) team prior to Exercise Pitch Black 08. One ABM team – the control team – prepared for Pitch Black 08 by supporting normal flying operations. A second ABM team prepared by taking part in Exercise Black Skies 08; the synthetic environment provided in Black Skies 08 was designed to simulate Pitch Black 08 as closely as possible in terms of mission scenarios, order of battle, airspace, procedures, and tactics.

The evaluation of the training provided in Black Skies 08 was carried out using the four levels of criteria suggested by Kirkpatrick (1959): Information was gathered about the ABM team's reactions to the virtual mission preparation, the learning that occurred over the course of the virtual mission preparation, the impact of the virtual mission preparation on performance in the subsequent live warfighting exercise, and the broader value to the organisation of the virtual mission preparation.

The outcomes from this study provide support for the view that synthetic training technologies can have a significant impact on the ability of RAAF warfighting teams to perform their mission in large-scale, complex, and dynamic warfighting situations. The ABM team that took part in Black Skies 08 provided positive evaluations of the training experience, their performance improved over the course of the virtual mission preparation, and during Pitch Black 08 they outperformed the ABM team that prepared for Pitch Black 08 by supporting normal flying operations. In addition, the virtual mission preparation demonstrated a broader organisational and operational value to the RAAF: it provided the White Force with the opportunity to identify deficiencies in, and mitigate risks associated with, the Pitch Black 08 mission scenarios; it also allowed the ABM Team to refine their Pitch Black 08 plans and procedures, enabling them to more effectively utilise the valuable training opportunity presented by a large-scale, live warfighting exercise.

These outcomes lend weight to the assertion that the RAAF could benefit significantly from the broad application of synthetic team and collective training technologies (Air Power Development Centre, 2007); however, further research is required into factors that influence the effectiveness and efficiency of team and collective training in synthetic environments. The potential impact of these technologies will also be constrained by their method of employment and by their accessibility: If experiences of the kind provided during Black Skies are made available infrequently, and only to small groups of individuals, their full potential will not be realised. This has implications for the simulation infrastructure used to provide these experiences. It is unlikely that existing RAAF simulation assets will be able to provide frequent and regular synthetic team and collective training for large numbers of operators. Development of the appropriate infrastructure will require significant investment, and it is important that this investment is justified and guided by rigorous science.

Key Recommendations:

1. RAAF should expand its capacity to provide synthetic team and collective training for its warfighters.
2. RAAF should support further research into the effective and efficient use of synthetic team and collective training technology.
3. RAAF (and the ADF more broadly) should invest in dedicated infrastructure for synthetic team, collective, and joint training.
4. RAAF should utilise DSTO's research experience to guide further investment in, and application of, tools and methods for synthetic team and collective training.
5. RAAF should expand its participation in coalition synthetic training exercises, and facilitate the conduct of collaborative research and development with coalition partners.

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1. Introduction

The first principle of Australian Defence Force training doctrine is that our forces should train as they operate (Australian Defence Force Warfare Centre, 2006). For air warfare command and control teams, however, the opportunity to take part in training that faithfully replicates or simulates operational circumstances and environments is rare, largely restricted to participation in large-scale, live exercises such as Pitch Black and Talisman Sabre. The scarcity of these valuable training opportunities has generated considerable interest in the use of synthetic environments as a means of supplementing or augmenting live training. In *The Future Air and Space Operating Concept* (Air Power Development Centre, 2007), virtual and simulated environments are identified as crucial to building appropriate skill sets and experience in Royal Australian Air Force (RAAF) warfighters.

There are clear benefits to providing team and collective training in a synthetic environment (Knerr, Breaux, Goldberg, & Thurman, 2002; Schiflett, Elliott, Dalrymple, Tessier, & Cardenas, 2000). First, there are significant savings associated with the reduced demand on platforms and personnel. This is particularly pertinent in the case of the RAAF, which is constrained in its capacity to develop its forces by virtue of its relatively small size and resource availability (Air Power Development Centre, 2007). Second, it is possible to generate complex, dynamic training scenarios free from safety or environmental concerns. The use of synthetic environments can provide training opportunities that cannot be made available in the real world, and which in some respects are more operationally valid than live training (Knerr et al., 2002). Third, the use of synthetic environments can enhance preparedness by giving command and control teams the opportunity to train, as they fight, on a more regular basis (Schiflett et al., 2000).

What is not clear is the extent to which team and collective training in a synthetic environment actually leads to more effective performance in a live warfighting environment. The principal aim of this study, in which we provided a RAAF command and control team with virtual mission preparation prior to a live warfighting exercise, was to address this question. In the introduction to this report, first we critically review the literature on the effectiveness of team and collective training in synthetic environments. Second, we outline the broad and specific research goals of this study, and state the relevant research hypotheses.

1.1 Previous Research on the Effectiveness of Team and Collective Training in Synthetic Environments

The most widely used framework for the evaluation of training programs is Kirkpatrick's (1959) four-level model (Goldstein & Ford, 2002; Kraiger, 2002), comprising the criteria *Reaction*, *Learning*, *Behavioural*, and *Results*. Reactions criteria relate to what trainees thought of the program. Learning criteria assess the extent to which trainees learnt the principles, facts, or techniques specified as training objectives. Behavioural criteria are concerned with the changes in job performance resulting from the training. Results criteria refer to the ultimate value of the training program to the organisation, such as improvement in quantity or quality of output, or mitigation of risk. The review of the literature that bears on the question of the effectiveness of collective training in synthetic environments is organised within this

framework; consistent with training research more generally, however, there is no literature that explicitly attempts to evaluate Kirkpatrick's Results criteria.

This literature review is restricted to research in the air warfare domain (for an overview of the application and efficacy of virtual training in other military domains see Stone, 2002, and Knerr et al., 2002). Almost exclusively, this research is the product of collaborative research by the United Kingdom's (UK) Defence Science and Technology Laboratory (DSTL) and the United States (US) Air Force Research Laboratory (AFRL). Over the past decade, DSTL and AFRL have been involved in a program of applied research investigating the use of synthetic environments to provide collective training for air operations. A number of exercises have been carried out in this program of research, including Trial VirtEgo (McIntyre, Smith, & Bennett, 2002), Trial SyCLONE (Smith & McIntyre, 2003), and Exercise Red Skies (Smith et al., 2006). Broadly speaking, these exercises have involved the creation of synthetic environments in which geographically dispersed aircrew from a variety of different roles – air-to-air, air-to-ground, and to a lesser extent airborne warning and control – participate in complex mission scenarios. These mission scenarios are based on real-world operational theatres, and are designed to support the aircrew's training needs throughout the complete mission cycle.

1.1.1 Evaluations of Reactions Criteria

Although participant reactions are not the most valid measure of training effectiveness, they can be used to establish the degree of user acceptance in a training system; favourable reactions to a training program are often a necessary condition for continued system use and development (Goldstein & Ford, 2002; Schreiber, Rowe, & Bennett, 2006). Over a period of several years, from 2002, the US AFRL (Schreiber et al., 2006) collected information of this nature from warfighters participating in five-day training research exercises at the distributed mission operations research site at Mesa, Arizona (*distributed mission operations* is the US term for team and collective training in synthetic environments). Feedback about the general value of the distributed mission operations training was provided by 327 F-16 pilots and 49 Airborne Warning and Control Station (AWACS) controllers, and 32 F-16 pilots provided information about the extent to which the training was capable of providing mission essential experiences. Overall, there was a strong user acceptance of the value of the training provided in distributed mission operations. The vast majority of participants agreed that the training had improved their combat mission readiness, and that they would recommend the training experience to other pilots or controllers. The distributed mission operations environment was also rated higher than all other training environments (including live exercises and regular training) in its capacity to provide experiences critical to the F-16 air-to-air operational role.

Favourable reactions to the collective training provided in synthetic environments were also reported in Trial VirtEgo (McIntyre et al., 2002) and Exercise Red Skies (Smith et al., 2006). The aircrew who participated in Trial VirtEgo were of the opinion that 60% of their role-specific mission essential tasks could be trained just as well in the synthetic environment as in a regular live training exercise; for 28% of these tasks, the synthetic environment was rated as a better training environment than live training exercises (McIntyre et al., 2002). However, reactions to the geographically dispersed collective training provided in Trial SyCLONE were less favourable, particularly in relation to the effectiveness of distributed planning, briefing, and debriefing systems (Smith & McIntyre, 2003).

1.1.2 Evaluations of Learning Criteria

There is also conflicting evidence regarding the extent to which collective training in synthetic environments facilitates the learning of teamwork processes and mission essential skills. The goal of ROADRUNNER 98 (Schiflett et al., 2000) was to investigate the impact that collective training in a synthetic environment has on mission performance. The exercise was unique in two respects. First, it focused on the performance of command and control teams – specifically, the weapons directors and air surveillance technicians that make up an Airborne Warning and Control Systems (AWACS) crew – with fighter aircraft performing a supporting role. Second, it focused on teamwork processes rather than mission essential tasks. Based on cognitive task analyses of the AWACS operational role, Schiflett et al. (2000) developed a taxonomy of command and control team performance designed to capture the core functions that comprise AWACS teamwork process. The principal dimensions were mission planning (the establishment of roles, responsibilities, and contingency plans), communication discipline (the extent to which individuals follow guidelines for communication exchange), communication content and timing (the extent to which the right information is exchanged with the right person, at the right time), and dynamic replanning (the ability to recognise when plans are no longer effective, to generate alternatives, and to decide upon a new course of action).

Over seven days, three AWACS teams each took part in seven complex missions designed to place the interdependencies within the team under stress. Supporting roles and enemy forces were played either by virtual or constructive entities. The overall performance of the AWACS teams improved over the seven mission scenarios. Although the synthetic training did not have a differential impact on the distinct teamwork dimensions, it did have a differential impact on the different mission phases, with overall performance improvement attributed to better performance in the mission execution and debriefing phases of each scenario. Schiflett et al. (2000) reported that the debriefing experience was found to be particularly beneficial to the AWACS crew: as the duration of an AWACS flight extends well beyond the flight duration of a particular set of combat aircraft, the AWACS crew do not usually debrief with pilots after an operational mission.

The results of Trial SyCLONE (Smith & McIntyre, 2003) were less positive. The goal of this exercise was to explore the relative benefit to Royal Air Force (RAF) aircrew of distributed versus collocated mission training. RAF and US aircrew, performing both air-to-air and air-to-ground roles, took part in two days of virtual missions. Not only did the performance of the aircrew fail to improve over these missions, but there was in fact a drop in performance across a majority of the mission objectives. The criteria on which the performance loss was most dramatic included the effectiveness of mission planning, the degree to which each team member understood their place in the broader air operation, review of tactics as a result of lessons learned, and performance of role-specific tasks. Furthermore, the trust between coalition aircrew decreased over the course of the mission. Smith and McIntyre concluded that geographic dispersion during collective training in synthetic environments has a negative impact on training value, with the UK and US aircrews unable to build rapport or develop inter-team cohesion.

Smith and McIntyre (2003) noted that on one level, Trial SyCLONE could be considered a success: the US and UK aircrew were able to plan, brief, fly, and debrief a complex mission. However, they also pointed out that Trial SyCLONE was clearly not effective in providing high value mission training, and cautioned that simply linking simulators to provide a common synthetic battlespace is not sufficient to provide effective training for air operations.

1.1.3 Evaluations of Behavioural Criteria

The extent to which learning that occurred in a synthetic training environment transfers to performance in a live warfighting environment was examined in Trial VirtEgo (McIntyre et al., 2002) and Exercise Red Skies (Smith et al., 2006).

The goal of Trial VirtEgo was to provide Royal Air Force (RAF) aircrew with virtual mission preparation for the live flying phase of a weapons instructors course. The trial was specifically targeted at providing training in the high-level teamwork processes essential to successful air operations; the criteria measured included communication and coordination, the ability to build and maintain situation awareness, and to make tactical decisions in a complex and dynamic environment.

In the virtual preparation phase, the aircrew undertaking the weapons instructors course took part in two full missions. Over the two mission days, there was an improvement in the collective performance of the aircrew across the majority of criteria; in most cases this improvement was maintained in the first mission of the live flying phase of the weapons instructors course. However, ratings of performance on criteria related to decision making and adaptability in the first mission of the live flying phase were substantially lower than in the final mission of the virtual mission preparation. It is also worth noting that the virtual mission preparation had no impact on the standard with which aircrew utilised role-specific skills (i.e., non-collective *taskwork* skills) within the collective environment; this finding is consistent with the results of other synthetic training exercises such as Trial SyCOE (McIntyre & Smith, 2000) and Trial SyCLONE (Smith & McIntyre, 2003).

McIntyre et al. (2002) argued that the value of the training provided in trial VirtEgo would be confirmed if performance of the candidates in the initial stages of the live flying phase was enhanced. Although they reported that the instructors on the course noted that the candidates performed better than is usual on the first day of the live flying phase, the design of the study – specifically, the lack of a control group – did not permit a rigorous test of this hypothesis. The particular nature of the transfer context – a weapons instructors course – also detracts from the ability to generalise the findings of this study to larger-scale warfighting contexts.

Exercise Red Skies (Smith et al., 2006) was far broader in scope: the primary goal was to investigate the benefits of conducting virtual mission preparation prior to a large-scale live exercise (Exercise Red Flag). In the synthetic environment provided in Red Skies, RAF and USAF aircrew flew missions similar to those that they would later fly in the live environment of Red Flag. The missions flown during the virtual and live exercises were matched in terms of coalition package, mission type (air interdiction, close air support, and time-sensitive targeting), Air Tasking Order (ATO), rules of engagement, and geographical location (the Nellis Air Weapons Range in Nevada, USA). According to Smith et al. (2006) the only major

difference between the Red Skies and Red Flag missions was that (1) there were a larger number of aircraft involved in Red Flag, and (2) both day and night missions were flown during Red Flag, whereas only day missions were flown during Red Skies.

In order to quantify the training benefits of the virtual mission preparation, Smith et al. (2006) used surveys to measure participants expectations about collective training in synthetic environments, as well as their reactions to the virtual mission preparation provided in Red Skies. The mission performance of the aircrew during both the synthetic exercise and the subsequent live-fly exercise was assessed by subject matter experts. Although Smith et al. do not provide sufficient information for a meaningful interpretation of the survey results, post-exercise interviews with the aircrew suggest that Red Skies was regarded as a valuable spin-up activity for Red Flag. Furthermore, mission performance in the live exercise was rated by the subject matter experts as appreciably higher than in the synthetic exercise.

The Red Skies study provides some evidence for the benefits of using synthetic environments in the preparation of teams of warfighters for large-scale, live training exercises. However, from the data that is reported it is not possible to determine the extent to which learning occurred over the course of the virtual mission preparation. As was the case in Trial VirtEgo, there is also no evidence to indicate whether aircrew that received virtual mission preparation for Red Flag outperformed aircrew that prepared for Red Flag using traditional methods.

1.2 The Current Program of Research

The present study forms part of a collaborative research program between DSTO's Air Operations Division and the US AFRL's Human Effectiveness Directorate, under the auspices of Project Arrangement PA-AF-0025: Distributed Mission Training Research. The broad goal of this program of research is to develop and evaluate tools and methods for providing effective, operationally-relevant, synthetic team and collective training for air combat. Previous studies conducted under this program include Pacific Link I (Crane et al., 2006) and Pacific Link II (Best et al., 2007). The current study had both broad and specific research goals. The broad research goal was to investigate the effectiveness of a range of tools and methods for structuring and managing RAAF synthetic team and collective training. The method and outcomes relating to this broad goal are presented in a companion report (Tracey et al., 2009). The specific research goal, and the focus of this report, was to investigate the potential benefits to the RAAF of using synthetic environments to provide mission preparation for live, large-scale training exercises. The synthetic exercise that was used to provide this virtual mission preparation was named Exercise Black Skies 08, and was conducted in the Air Operations Experimentation Centre at DSTO Melbourne in May 2008, two weeks prior to Pitch Black 08. Pitch Black is a biennial, live air combat training exercise hosted by the RAAF, involving participants from a number of foreign military forces (Department of Defence, 2009).

This study builds upon the existing research in a number of ways. First, the study examines the benefits of virtual mission preparation in the Australian warfighting context, rather than that of the US or the UK. The RAAF is indeed required to be able to integrate – to essentially work as a single system – with the air forces of the US and the UK. However, as a result of Australia's broader strategic context there are significant cultural, organisational, and operational differences between the RAAF and the air forces of its primary allies (Air Power

Development Centre, 2007). Second, we extend the research on the benefits of virtual mission preparation from the fighter aircrew role to that of command and control teams; specifically, Air Battle Management (ABM) Teams from 41 Wing, Surveillance and Response Group. These teams are responsible for the tactical command and control of all air assets in the battlespace, and are typically comprised of a Tactical Director, and a number of Fighter Controllers. The Tactical Director allocates assets and manages operations within the air battle, overseeing and directing the Fighter Controllers, and communicates with other command elements and external agencies. The Fighter Controllers liaise with pilots in order to direct aircraft in accordance with instructions, procedures, the tactical plan, and as directed by the Tactical Director. ABM Teams deal with complex information from a variety of sources, make decisions in uncertain and dynamic situations, and have distinct but interdependent roles. These features of their role make them representative of command and control teams more generally. Third, we employ measures relating to the performance of mission essential tasks as well as measures relating to generic teamwork processes and motivational states critical to effective team performance: communication, information exchange, supporting behaviour, initiative and leadership, collective efficacy, and cohesion (Ilgen, Hollenbeck, Johnson, & Jundt, 2005; Kozlowski & Ilgen, 2006; Salas, Sims, & Burke, 2005). Finally, by employing a matched control group that received no formal training, this study permits a more rigorous evaluation of the absolute effectiveness of virtual mission preparation than permitted by previous studies.

1.2.1 Research Questions

As stated previously, the principal aim of this study was to investigate the potential benefits of using synthetic environments to provide mission preparation prior to a live warfighting exercise. Within this principal aim are several distinct research questions that permit an evaluation of the training provided in Exercise Black Skies according to Kirkpatrick's (1959) criteria:

Reactions Criteria:

1. What opinions do members of RAAF ABM Teams hold about the utility and applications of virtual mission preparation, and Exercise Black Skies in particular?
2. How do synthetic training environments such as the one employed in Exercise Black Skies compare to live exercises, and regular training, in the capacity to provide experiences critical to the ABM role?

Learning Criteria:

3. What impact does participating in team training in a synthetic environment have on key teamwork processes and motivational states?
4. What impact does participation in team training in a synthetic environment have on the performance of mission-essential tasks?

Behavioural Criteria:

5. Do ABM Teams that take part in virtual mission preparation demonstrate more effective team processes during live warfighting exercises than teams that prepare by supporting normal flying operations?
6. Do ABM Teams that take part in virtual mission preparation perform better in live warfighting exercises than teams that prepare by supporting normal flying operations?

Results Criteria:

7. What broader value is there for the RAAF in providing command and control teams with virtual mission preparation prior to live warfighting exercises?

A subset of these research questions can be associated with research hypotheses. Specifically, we predict that the training provided in Exercise Black Skies will result in an improvement in teamwork processes, motivational states, and the performance of tasks critical to the ABM team role. Furthermore, we predict that the learning that occurs over the course of the virtual mission preparation will transfer to the live warfighting environment, with the result that the ABM team that received the virtual mission preparation will perform better – on measures of both taskwork and teamwork – than the ABM team that prepared by supporting normal flying operations.

2. Method

2.1 Design and Participants

2.1.1 Design

A case study strategy was employed to examine the benefits of using synthetic environments to provide mission preparation for command and control teams prior to a large-scale, live warfighting exercise. The live exercise used as a vehicle for this study was Pitch Black 08, a biennial combined air and ground training exercise hosted by the RAAF and involving participants from a number of foreign military forces (Department of Defence, 2009). Pitch Black 08 took place around Darwin and Tindal in June, 2008, and the broad aim of the exercise was to test and improve the command and control in, and execution of, a multi-national coalition air campaign.

One ABM team – the control team – prepared for Pitch Black 08 by supporting normal flying operations, as well as taking part in additional training tailored specifically for the live exercise. This tailored preparation commenced two weeks prior to Pitch Black 08, and consisted predominantly of practice missions which involved control of Williamtown aircrew in smaller scale missions than those seen at Pitch Black 08. The missions generally escalated in difficulty over the work up period, but did not reach the complexity or difficulty of the Pitch Black 08 missions. During this work-up period the control ABM team attended pre-mission briefs and post-mission debriefs with the aircrew. This team were also asked to read the Pitch

Black 08 exercise documentation, which included the airspace control plan, the airspace defence plan, and the air surveillance plan. The members of the team were then required to sit a theory exam to ensure all documentation was understood. A second ABM team prepared for Pitch Black 08 by taking part in Exercise Black Skies 08. The synthetic environment provided in Black Skies 08 was designed to simulate Pitch Black 08 as closely as possible in terms of mission scenarios, order of battle, airspace, procedures, and tactics. A description of the mission scenarios is presented in Section 2.3.1.

As stated in the Introduction, the evaluation of the training provided in the virtual mission preparation – Black Skies 08 – was carried out using the four levels of criteria suggested by Kirkpatrick (1959): Information was gathered about the ABM team's reactions to the virtual mission preparation, the learning that occurred over the course of the virtual mission preparation, the impact of the virtual mission preparation on performance in the subsequent live warfighting exercise[1], and the broader value to the organisation of the virtual mission preparation.

2.1.2 Participants

Two ABM Teams from 41 Wing (WG), Surveillance and Response Group (SRG), participated in the study. Each team consisted of a Tactical Director, and three Fighter Controllers in direct control roles, all of whom possessed operational experience.

The Fighter Controllers were allocated to either the virtual mission preparation or control conditions by 41WG in a quasi-random manner; random allocation was constrained by the desire to produce ABM Teams that were matched in terms of the operational experience of their members, and by the availability of individual Fighter Controllers for the virtual mission preparation phase of the study.

2.1.3 White Force and Assessor

The execution of the virtual mission preparation was managed by a White Force consisting of a White Force Mission Director, a Red simulation operator (SIMOP) coordinator, five SIMOPs, and an Air Battle Director. The role of the White Force Mission Director was contracted to Milskil Integrated Solutions (the company responsible for developing and managing the execution of the Pitch Black 08 vignettes), and was filled by an ex-RAAF fighter pilot. The Air Battle Director and the five SIMOPs were members of 41 WG SRG, and the Red SIMOP coordinator was a DSTO staff member who possessed operational experience as an ABM with the RAAF. The Blue SIMOPs manipulated the Blue Force air assets under the direction of the White Force Mission Director. The Red SIMOPs, under the direction of the Red SIMOP coordinator, were responsible for both manipulating the synthetic fighter assets under the control of the ABM team and simulating the communications of those aircraft pilots. In both Black Skies 08 and Pitch Black 08, the evaluation of taskwork performance and teamwork

[1] For reasons of both safety (e.g., conducting research in a live-control environment) and resources (e.g., access to an appropriate assessor) we were only able to assess the performance of the ABM Teams on the first two days of Pitch Black 08.

processes was carried out by an assessor from Surveillance and Control Training Unit (SACTU), 41WG SRG.

2.2 Measures

2.2.1 Measures of Trainee Reactions to the Virtual Mission Preparation

2.2.1.1 Fighter Controller Reactions Survey

General opinions about mission training through distributed simulation, and reactions to the training provided in Black Skies 08 in particular, were assessed using the Fighter Controller Reactions Survey. This 58-item survey was adapted for the RAAF ABM context from a questionnaire developed by AFRL and DSTL; this questionnaire was designed to be used by AWACS controllers – who perform a similar function to RAAF Fighter Controllers – for the purposes of the evaluation of coalition mission training research exercises (Smith, et al., 2006). Participants used a 7-point scale (1 = *strongly disagree*, 7 = *strongly agree*) to rate the extent to which they agreed with statements such as 'EBS 08 has helped me improve my team coordination skills' and 'mission training through distributed simulation provides realistic training and experience.'

2.2.1.2 Training Environments Survey

The relative utility of virtual exercises as an environment in which to train experiences critical to the ABM role was assessed using the Training Environments Survey. The survey, also adapted from a questionnaire developed by AFRL and DSTL for the evaluation of coalition mission training research exercises (Smith, et al., 2006), contains 66 items representing experiences commonly encountered in RAAF ABM team missions. Participants used a 5-point scale (1 = *not at all*, 5 = *to a great extent*) to indicate the extent to which it is reasonably possible to provide each experience in each of three different training environments: (1) virtual exercises such as Black Skies 08, (2) live exercises such as Pitch Black 08, and (3) training at their home unit. The first two environments have been described previously. The training that ABM teams receive at their home unit consists largely of the *individual* training of Fighter Controllers – both live and simulated – in procedures and tactics critical to the Air Battle Management role. ABM Teams actually rarely train as a team prior to deployment, aside from that training offered in live exercises such as Pitch Black.

2.2.2 Motivational State Measures

2.2.2.1 Collective Efficacy

The collective efficacy of the team that received the virtual mission preparation was assessed using an 8-item scale that focused on the individual's perception of the team's ability to effectively cope with the challenges of their task. Participants were asked to rate, on a 7-point scale (1 = *strongly disagree*, 7 = *strongly agree*), the extent to which they agreed with statements such as 'this team can meet the challenges of the task' and 'this team will cope if the task becomes more complex.' The measure was adapted from a scale developed by Kozlowski et al. (2001) and described more comprehensively by DeShon et al. (2004), who reported a one-factor solution with coefficient alphas ranging from .95 to .96 over three successive administrations.

2.2.2.2 Cohesion

The cohesion of the team that received the virtual mission preparation was assessed using a 6-item scale focusing on the extent to which the team members work together to accomplish their task. Participants rated, on a 7-point scale (1 = strongly disagree, 7 = strongly agree), the extent to which they agreed with statements such as 'the members of this team work hard to get things done' and 'the members of this team make each other feel like doing a good job.' The measure was adapted from Siebold and Kelly's (1988) instrumental cohesion scale, with a reported coefficient alpha of .83.

2.2.3 Taskwork Performance Measure

Taskwork performance was assessed against a hierarchical set of measures designed to capture all the mission-essential tasks required of an ABM team in conducting a Defensive Counter Air operation (Hasenbosch & Best, 2007), focusing only on those aspects of the task that rely on teamwork. The hierarchy contains six highest-level categories (develop and brief mission plan, establish military liaison, manage information systems, control air space, conduct defensive counter air, and protect key points and vital assets) and 47 items at the lowest level of measurement. The six highest-level categories are linked to the tactical level of the Australian Joint Essential Tasks List (McCarthy et al., 2003); this list presents a comprehensive description of all tasks essential to the preparation, planning, and conduct of Australian Defence Force (ADF) operations. The system of performance measurement employed in this study enables commanders to identify the strengths and weaknesses of teams in the broader context of required operational capability. The assessor used a 5-point anchored scale (1 = *terrible*, 2 = *inferior*, 3 = *passable*, 4 = *good*, 5 = *excellent*; taken from Spector, 1992) to rate the performance of the ABM team against the behavioural criterion attached to each lowest level item.

Table 1: Behavioural anchors for the scale used to assess the four dimensions of teamwork processes

Poor Behaviours	Excellent Behaviours
Communication	
Team members consistently demonstrated improper use of phraseology, excess chatter, incomplete reports, inaudible communication	Team members displayed no instances of improper phraseology, excess chatter, incomplete reports, inaudible communication
Information Exchange	
Team members failed to use information from all available sources, did not pass on information before having to be asked, did not provide situation updates	Team members made use of information from all available sources, passed on information without having to be asked, provided good situation updates
Supporting Behaviour	
Team members did not monitor one-another for errors, or take action to correct errors when they occurred. They did not request or offer assistance when it was required to adjust workload within the team	Team members consistently monitored one-another for errors and took action to correct errors when they occurred. They requested and offered assistance when required to adjust workload within the team
Initiative and Leadership	
Team members did not offer guidance or suggestions to others when required. They were unclear about their own, and the team's priorities, or failed to state these clearly	Team members offered guidance and suggestions to others when required. They understood their own, and the team's priorities and stated these clearly

2.2.4 Teamwork Processes Measure

Teamwork processes were assessed on a scale comprised of the four principal dimensions identified by Smith-Jentsch, Zeisig, Acton, and McPherson (1998): communication, information exchange, supporting behaviour, and initiative and leadership. These dimensions were identified by Smith-Jentsch et al., (1998) from an analysis of performance data from US Navy combat information centre teams. Smith-Jentsch et al. included only the factors which were directly observable and also involved team performance (i.e., they excluded individual-level behaviours). These dimensions and slight variations thereof have been widely utilised in the team training literature (e.g., McIntyre and Salas, 1992; Serfaty, Entin & Johnston, 1998; Smith-Jentsch, Johnston & Payne, 1998; Rousseau, Aubé & Savoie, 2006). Participants (and the assessor) were asked to rate the quality of teamwork processes using a 7-point scale[2] anchored with descriptions of poor and excellent behaviours related to each dimension; the behavioural anchors are listed in Table 1.

[2] In Pitch Black 08, the assessor employed a 5-point scale – incorporating the same behavioural anchors as the 7-point scale - to rate teamwork processes. For ease of comparison with Black Skies 08 data, these ratings were transformed to a 7-point scale.

2.3 The Virtual Mission Preparation Environment

The virtual mission preparation provided for the ABM team in Black Skies 08 was designed to match, as closely as possible, the environment in which they would work and the tasks which they would be required to perform during Pitch Black 08. A comprehensive description of the physical environment and simulation infrastructure employed in the virtual mission preparation phase of the study is provided in the companion report (Tracey et al., 2009); here, we provide a brief overview of the mission scenarios, management, physical environment, information systems, and scenario generation in Black Skies 08.

2.3.1 Mission Scenarios in Exercise Black Skies 08 and Pitch Black 08

Pitch Black 08 was comprised of a series of mission scenarios (or *vignettes*) which, over the course of the exercise, portrayed an escalation in tension between the opposing Blue and Red forces and a progression of military action. The vignettes varied in terms of training objectives, order of battle, rules of engagement, airspace, threats, and targets; they did not differ in terms of difficulty or complexity. Broadly speaking, the Blue Force participants were required to conduct a variety of missions such as offensive counter air (OCA), offensive air support (OAS), deep strike, destruction of enemy air defences, and joint personnel recovery; the Red Force participants responded by employing defensive counter air (DCA) tactics. The 41WG ABM Teams worked in shifts to provide tactical command and control support to the Red Force.

Of the seven vignettes developed for Pitch Black 08, four were used in the virtual mission preparation provided in Black Skies 08: Vignette A, involving a Blue Force OCA mission (Day 1 of EBS 08); Vignette B, involving Blue Force OCA and strike (Days 2 and 5); Vignette D, involving a Blue Force joint personnel recovery mission (Day 3); and Vignette E, which involved a Blue Force deep strike mission (Day 4). In each Black Skies 08 vignette, between 40 and 60 Blue and Red air entities were generated.

2.3.2 Physical Environment in Exercise Black Skies 08

In Pitch Black 08, the ABM team operated out of the Tactical Control Centre, Eastern Regional Operations Centre, at RAAF Williamtown. For Black Skies 08, a scaled-down version of Tactical Control Centre was constructed in the Air Operations Experimentation Centre (AOEC) at DSTO Melbourne. The layout of the AOEC during Black Skies 08 is depicted in Figures 1 and 2: Figure 1 shows the positions of members of the ABM team and the White Force, and Figure 2 shows the view from the station of the Tactical Director, in front of which are the stations of the three Fighter Controllers under his command.

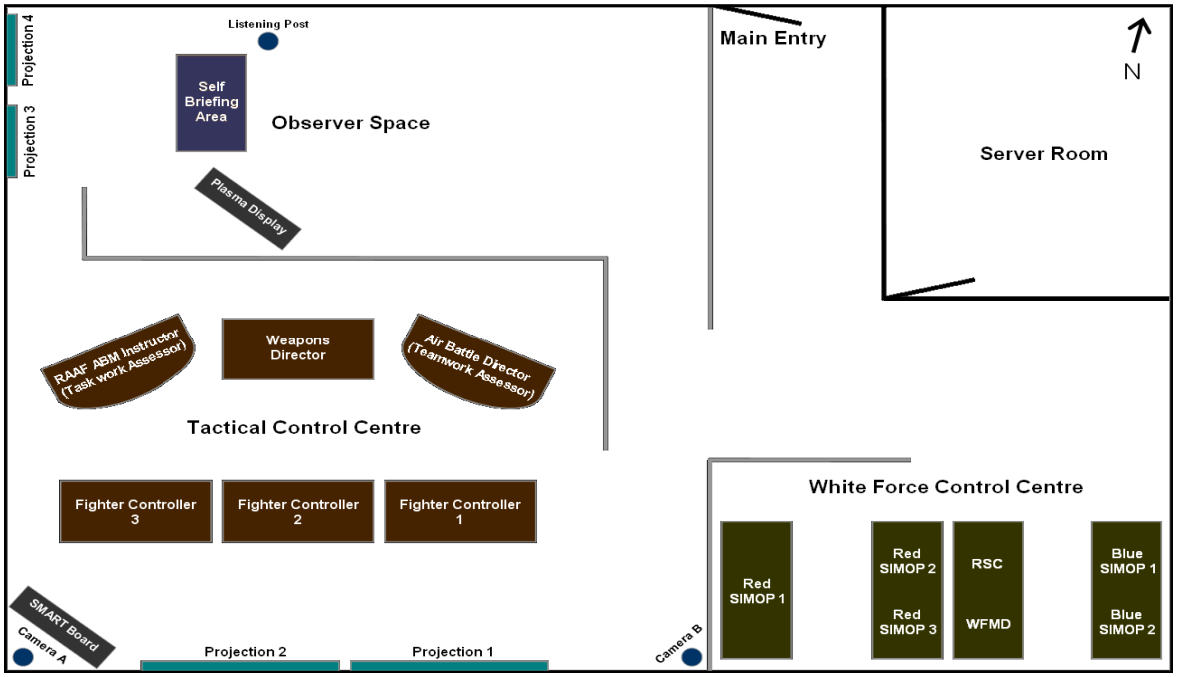

Figure 1: A top-down representation of the simulation facility, showing the control cells and positioning of personnel

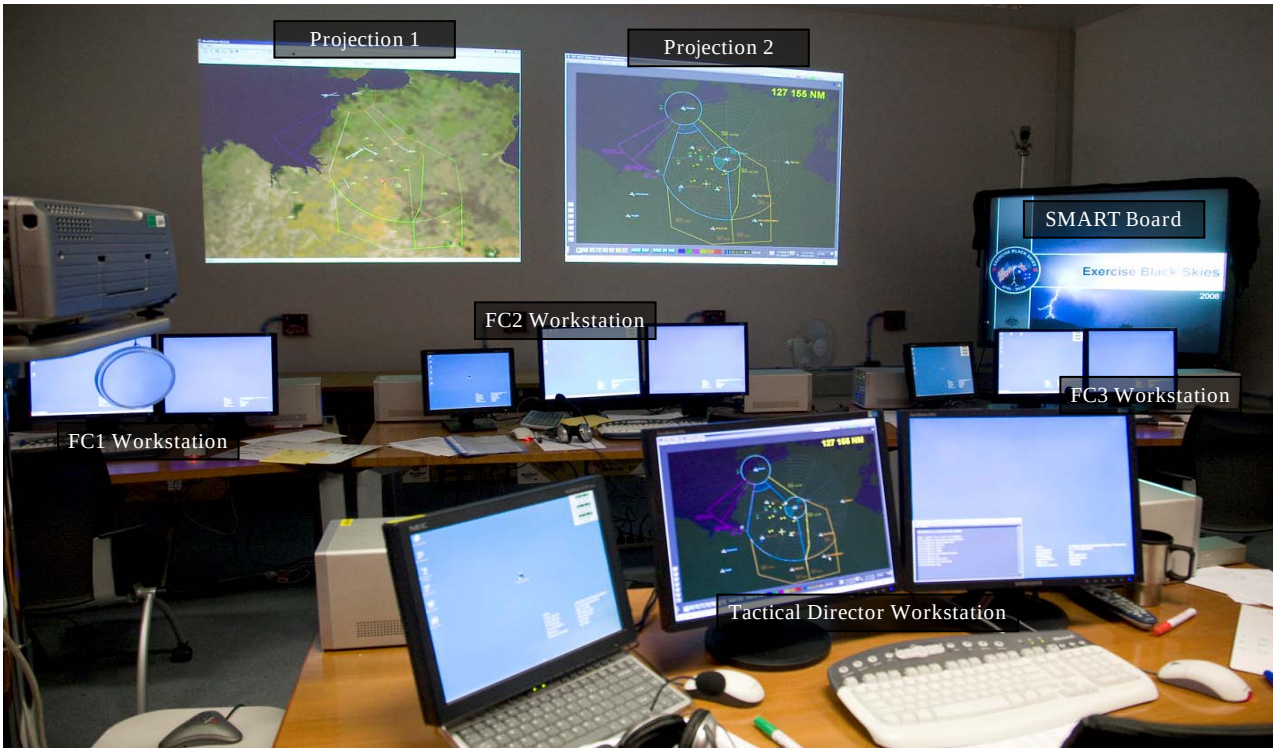

Figure 2: The tactical control centre, showing the position of members of the Tactical Director and the three Fighter Controllers (FC), the layout of operator workstations, and the visual tools used during after action review (the SMART Board and projection surfaces)

2.3.3 Information Systems in Exercise Black Skies 08

The ABM team was provided with information systems which faithfully replicated the operational command and control system used by the RAAF: the Solipsys tactical situation display software, a simulation of the radio and intercom equipment, and the Toteboard application (used to collect and disseminate information about the fuel and weapon status of aircraft).

2.3.3.1 Scenario Generation in Exercise Black Skies 08

The White Force used Pilot Simulation Interface software to create and control entities. Each instance of PSI was connected to a server operating the VR-Forces software, which modelled all the aircraft in the simulation environment and broadcast the information via a Distributed Interactive Simulation (DIS) protocol.

An Air Defence Ground Environment Simulator (ADGESIM) server application called SensorLink was used to model the Pitch Black 08 radar types and sites, and to translate the detection of entities received via the DIS protocol to a plot protocol compatible with the multiple source correlator / tracker.

The multiple source correlator / tracker was connected to each instance of the Solipsys tactical situation display software; this software was configured with airspace and waypoint data, and a RAAF-developed user profile which defines aspects such as data block fields, identify friend or foe (IFF) decoding, and a multitude of appearance settings.

2.4 Virtual Mission Preparation Procedure

The virtual mission preparation took place two weeks prior to the commencement of Pitch Black 08. On the first day of the virtual mission preparation the ABM team was briefed on the purpose and goals of the exercise, the exercise scenario, the manner in which their taskwork performance and teamwork processes would be evaluated, and the schedule of events. They completed the team cohesion, collective efficacy, and teamwork processes measures, and were then allocated time to familiarise themselves with the setup of the command and control systems.

One mission was run on each day of Black Skies 08, beginning on the afternoon of the first day. The procedure surrounding each mission consisted of the following key events: scenario update, mission preparation, mission execution, measurement session, after action review (AAR), and exercise feedback[3].

In the scenario update, the ABM team were briefed on expected threats, order of battle, rules of engagement (ROE), airspace, and enemy intent. The preparation time was used to plan for the impending mission. In each mission, the ABM team was required to command the air assets defending Red airspace and key points against the larger and technologically superior

[3] The instability of the simulation system necessitated minor modifications to the schedule; see Tracey et al. (2009) for greater detail.

Blue Force. Their taskwork performance and teamwork processes were assessed by the SACTU assessor and the Air Battle Director respectively; the taskwork assessment was completed using a semi-automated performance assessment and feedback tool developed by DSTO in partnership with the RAAF (see Tracey et al., 2009, for a description of this tool). In the measurement session following each mission, the ABM team completed the team cohesion, collective efficacy, and teamwork processes measures. In the AAR session, the ABM team received structured feedback about the effectiveness of their teamwork processes, and their performance was evaluated against the specific training objectives contained in the ABM DCA hierarchy. This performance feedback was supported by replays of the ground truth synchronised with replays of the tactical displays and communications. In the exercise feedback sessions the ABM team completed the Fighter Controller Reactions Survey (Day 4), the Training Environments Survey (Day 5), took part in structured interviews relating to the utility of the simulation tools and training methods employed in Black Skies 08, and provided general feedback about the exercise.

2.5 Exercise Pitch Black Procedure

During the first week of Pitch Black the ABM teams conducted work up missions as training for the exercise. Prior to the first day of flying there was a Mass Air Brief in which all exercise participants were familiarised with the specifics of the exercise including the scenarios, airspace, procedures, and manning requirements. During the exercise the ABM teams controlled one defensive counter air mission a day. These missions were preceded with a brief by the Tactical Director. The Tactical Director briefed the aircrew using video conferencing and then briefed the ABM team. The ABM team brief consisted of issues such as communications requirements, airspace layout and restrictions and any points which came out of the brief with the aircrew. Following mission execution the Tactical Director debriefed the ABM team and then the aircrew.

3. Results

The results are reported within the framework of Kirkpatrick's (1959) four criteria for the evaluation of training programs: Reaction, Learning, Behavioural, and Results. In the first section, we report the ABM team's general impression of Black Skies 08 as a training activity, as well as their beliefs about the broad and specific utility of virtual mission preparation. In the second section, we report the extent to which Black Skies 08 resulted in improvements in the ABM team's taskwork performance, teamwork processes, and key motivational states. In the third section, the Pitch Black 08 performance of the ABM team that received the virtual mission preparation is compared to that of a team that prepared by supporting normal flying operations. In the final section, we highlight some of the ways in which Black Skies 08 was of considerable organisational value to the RAAF.

3.1 Reaction to the Training Provided in the Virtual Mission Preparation

3.1.1 Fighter Controller Reactions Survey

The mean ratings of ABM team member agreement with all items in the Fighter Controller Reactions Survey are presented in Table A1, Appendix A. Only the more salient results, by category, will be elaborated in this section.

3.1.1.1 Overall Utility and Potential Applications

At a broad level, members of the ABM team viewed Black Skies 08 as a good use of their time, and would recommend the experience to other controllers. They agreed virtual mission preparation of this kind had considerable combat mission training value, and that it should be employed as both spin-up for live exercises and as part of their readiness training schedule.

3.1.1.2 Impact on Mission Skills and Readiness

Significantly, the ABM team reported that Black Skies 08 had improved their combat mission readiness, and that they would perform better as a controller as a result of Black Skies 08. More specifically, the ABM team felt that as a result of the virtual mission preparation they had improved their team coordination skills, combat situational awareness, tactical skills, and were better prepared to brief and lead a mission. However, they were ambivalent as to whether they had improved their mission planning skills, understanding of critical combat skills, or debriefing skills.

3.1.1.3 Specific Training Opportunities

The ABM team agreed that Black Skies 08 provided valuable experience across a number of areas that are critical to conducting the DCA mission, including: interacting with a variety of people and systems, team coordination, multiple complex presentations, and large force control. In fact, the ABM team felt that Black Skies 08 provided a training experience that is not available at their home unit; as a whole the team was equivocal as to whether their home unit routinely provided the opportunity to practice tactics in multiple aircraft environments, or to control aircraft against realistic threats. Although the ABM team agreed strongly that when they returned to their operational unit they would have the opportunity to use the skills learned during Black Skies 08, they were unsure whether the operations tempo at their home unit would help to maintain the skills learned during Black Skies 08.

3.1.1.4 Relation between Virtual Mission Preparation and Regular Training

Overall, the ABM team agreed that Black Skies 08 provided realistic training and experience. Importantly, the skills trained in Black Skies 08 were considered to be the same as those the ABM team required in the field. However, the ABM team were equivocal about both the extent to which the exercise environment itself was a realistic representation of combat, and whether the missions and engagements accurately represented how things happen in the operational world.

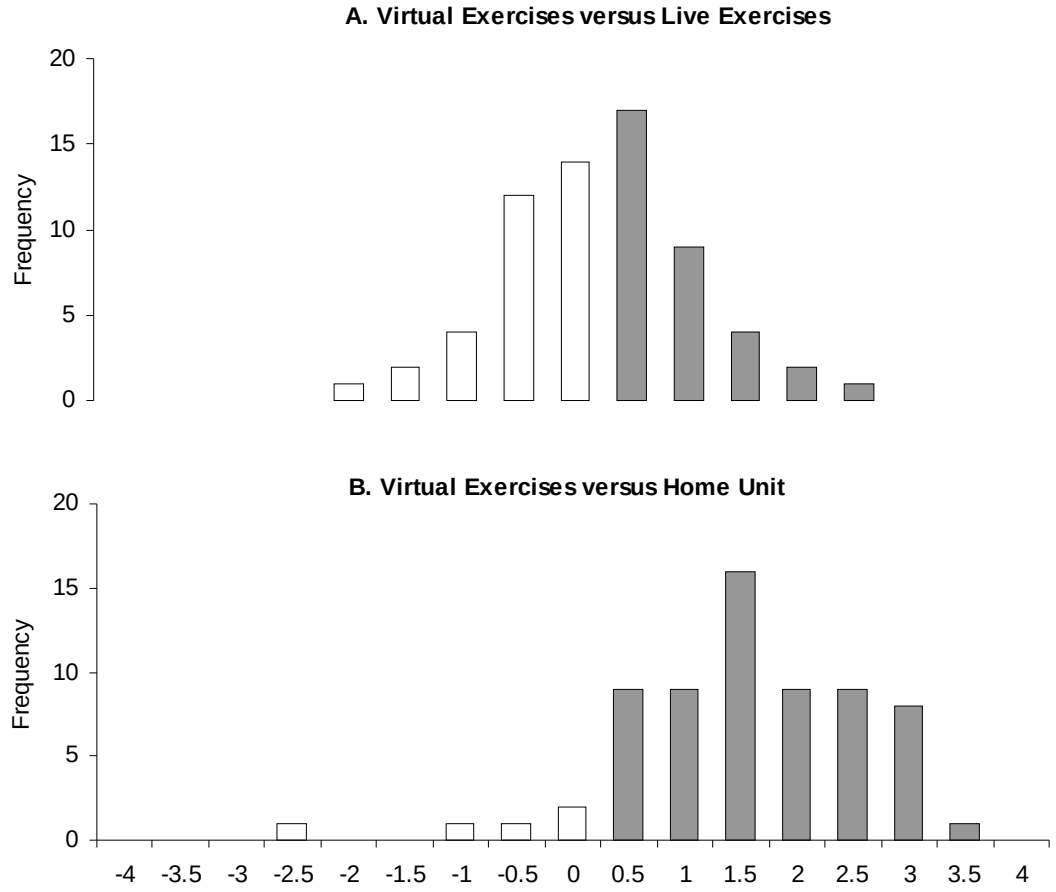

Figure 3: Frequency histograms showing the distribution of differences between suitability ratings for virtual exercises versus live exercises (Panel A) and home-unit training (Panel B) on a set of ABM training tasks. Difference scores are grouped into half-scale-point categories. Positive scores indicate that virtual exercises were rated as more suitable environments for given tasks, negative scores indicate that that virtual exercises were rated as less suitable.

3.1.1.5 Training Design and Procedure

From a system perspective, the scenarios were viewed as well designed with clear learning objectives. Although the missions and engagements were considered to be challenging, and helped the ABM team meet these learning objectives, they had no difficulty in keeping up with the pace of the missions.

3.1.2 Training Environments Survey

Overall, virtual exercises such as Black Skies 08 compared favourably to more established training environments in terms of the ability to provide experiences critical to the ABM role. The frequency histograms in Figure 3 show how the ABM team that participated in Black Skies 08 rated the relative suitability of virtual exercises, live exercises, and home-unit training

as environments for training a given set of ABM tasks[4]. Panel A shows the differences between suitability ratings given to virtual exercises and live exercises. Panel B shows the differences between suitability ratings given to virtual exercises and home unit training. Difference scores are grouped into half-scale-point categories in order to form the frequency histogram. Positive scores indicate that virtual exercises were rated as more suitable environments for given training tasks, while negative scores indicate that virtual exercises were rated as less suitable. Panel A shows that virtual exercises were rated as equal or more suitable (i.e., difference scores of zero or greater) than live exercises for training almost two-thirds of the training tasks (62%). Panel B shows that virtual exercises were rated as equal or more suitable than home-unit training for all but a few of the training tasks (94%).

3.1.2.1 Virtual Exercises compared to Live Exercises as Training Environments

Significantly, virtual exercises were regarded as just as suitable as live exercises for the training of core ABM team experiences such as tanker management and air refuelling, protection of high value airborne assets, prosecuting high-fast-flyers, and dynamic air combat manoeuvring.

Virtual exercises were also viewed as comparable to live exercises in their ability to provide experiences relevant to working with large groups (e.g., tracking of large Blue and Red Air groups, the safe control of large fighter groups and strike packages) and working in a difficult sensor and communications environment (e.g., dense internal and external communications, working with a degraded picture, the troubleshooting of primary and secondary sensors, and working in a radar / IFF / communications jamming environment). For the most part, virtual exercises were seen as equivalent to live exercises in their ability to provide experiences commonly part of complex mission scenarios, such as: various Rules of Engagement, a variety of enemy threats and tactics as well as a variety of friendly capabilities and tactics, a dynamic ground and air enemy order of battle, rapidly changing targets and priorities, and joint fires.

Some experiences common to complex mission scenarios were seen as more suited to the live exercise environment, including: operating in varied atmospheric conditions, force marshalling, and keeping track of flight and time-on-target deconfliction. However, aside from a small number of assets and roles not simulated in Black Skies 08 (e.g., working with electronic attack assets, working as check-in controller), the largest category of experiences for which virtual training environments were seen as less suitable than live training exercises related to interaction with external agencies: joint and combined operations planning, face to face mission planning (e.g., with fighter aircrew), Air Operation Centre coordination, external coordination with Air Traffic Control, coordination with other C2ISR players, and working with various ground parties (e.g., special operations forces, forward air control).

3.1.2.2 Virtual Exercises compared to Home Unit as Training Environments

Only a very small number of experiences were judged by the ABM team to be more suited to training within their home unit than within virtual exercises such as Black Skies 08. These included: acting as a liaison in a contingency operation or exercise, face to face mission

[4] Table A2, Appendix A, displays the mean ratings of the extent to which it was judged possible by the ABM team to provide critical experiences in virtual exercises such as Black Skies 08, live exercises such as Pitch Black 08, and home unit training environments.

planning with other elements (e.g., fighter aircrew), external coordination with Air Traffic Control, operating in varied atmospheric conditions, and hands-on platform familiarisation.

3.2 Learning over the course of the Virtual Mission Preparation

Over the course of Exercise Black Skies 08, the ABM team displayed a marked improvement in taskwork performance, teamwork processes, and on key motivational variables. Outcomes pertaining to these aspects of performance are described in detail below.

3.2.1 Evaluation of Taskwork Performance in Exercise Black Skies 08

Summary ratings on the principal dimensions of taskwork performance on the first and last days of the virtual mission preparation are displayed in Figure 4. Overall, the performance of the ABM team ranged from passable to good. The training appeared to have the greatest impact on tasks associated with the control of airspace, the management of information systems, and establishing military liaison; the training had the least impact on core DCA tasks, which includes factors such as the management of rules of engagement and the prioritisation of threats.

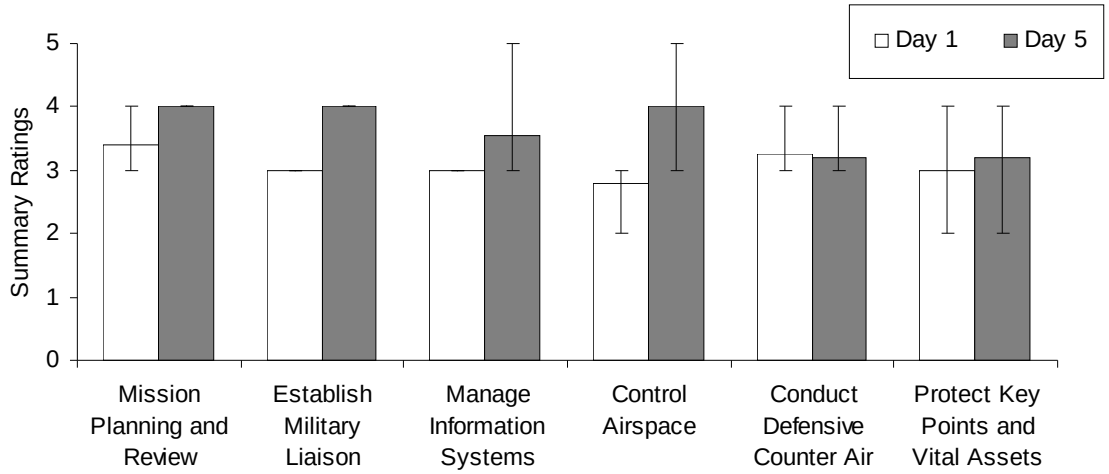

Figure 4: Summary ratings on the principal dimensions of taskwork performance of the team that received the virtual mission preparation for Day 1 and Day 5 of Exercise Black Skies 08. Error bars show the range of component performance ratings. For dimensions where no error bars are displayed all component ratings were the same.

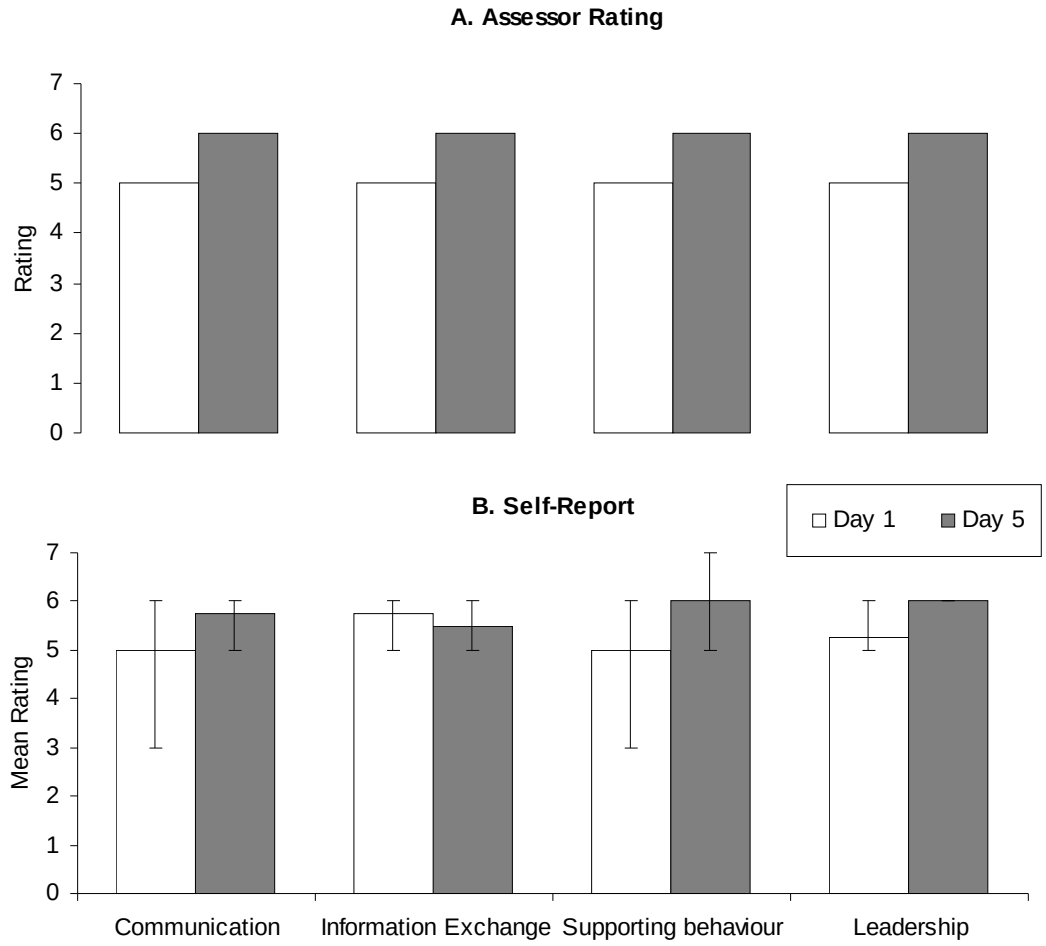

Figure 5: Assessor (Panel A) and mean self-report (Panel B) ratings of team processes for the team that received the virtual mission preparation on Day 1 and Day 5 of Exercise Black Skies 08. Error bars in Panel B show the range of self-report ratings provided by team members. Where no error bars are displayed all ratings were the same.

3.2.2 Evaluation of Teamwork Processes and Motivational States in Exercise Black Skies Black 08

The ABM team demonstrated a more uniform improvement in teamwork processes – as opposed to taskwork performance – over the course of the virtual mission preparation. As illustrated in Panel A of Figure 5, the team's communication, information exchange, supporting behaviour, and initiative and leadership behaviours were rated by the assessor as more effective on the last day of Black Skies 08 than they were on the first day. For the most part, the ABM Teams' ratings of their own teamwork processes indicated a similar improvement (Panel B of Figure 5). As shown in Figure 6, the ABM team reported a concomitant increase in attitudes that facilitate effective team performance – collective efficacy and instrumental cohesion – over the course of Black Skies 08.

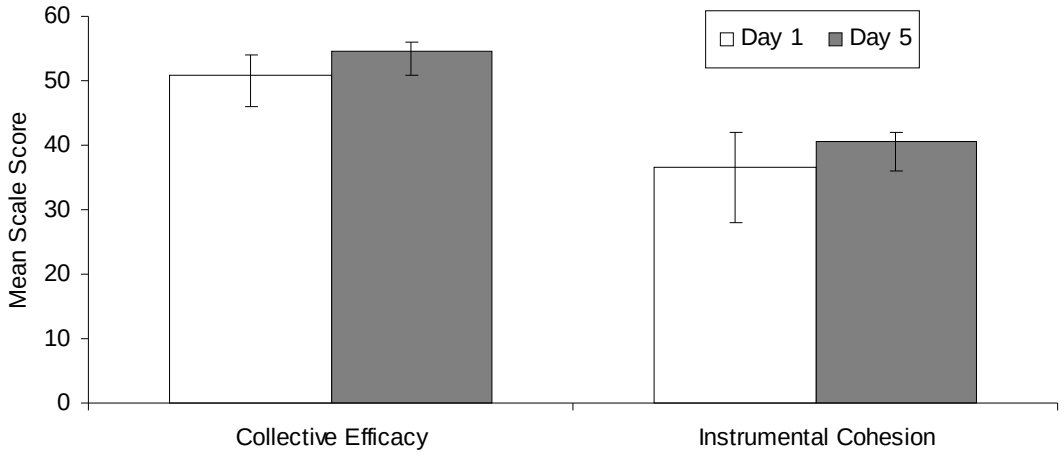

Figure 6: Mean collective efficacy and instrumental cohesion scale scores, for the team that received the virtual mission preparation, on Day 1 and Day 5 of Exercise Black Skies 08. Error bars show the range of ratings provided by team members.

3.3 The impact of Virtual Mission Preparation on Performance in a Live Warfighting Exercise

3.3.1 Evaluation of Taskwork Performance during Pitch Black 08

Summary ratings on the principal dimensions of taskwork performance for the team that received the virtual mission preparation and the control team on Days One (Panel A) and Two (Panel B) of Pitch Black 08 are displayed in Figure 7. Both teams performed at an acceptable level. Overall, however, the team that received the virtual mission preparation outperformed the team that prepared by supporting normal flying operations. On Day One, the greatest differences between the teams were on tasks related to establishing military liaison, management of information systems, and protection of key points and vital assets. On Day Two the gap in performance between the teams was quantitatively and qualitatively different: the gap was less apparent overall, and most noticeable on tasks related to the control of airspace – these particular tasks were performed by the teams to a roughly equivalent level on the preceding day.

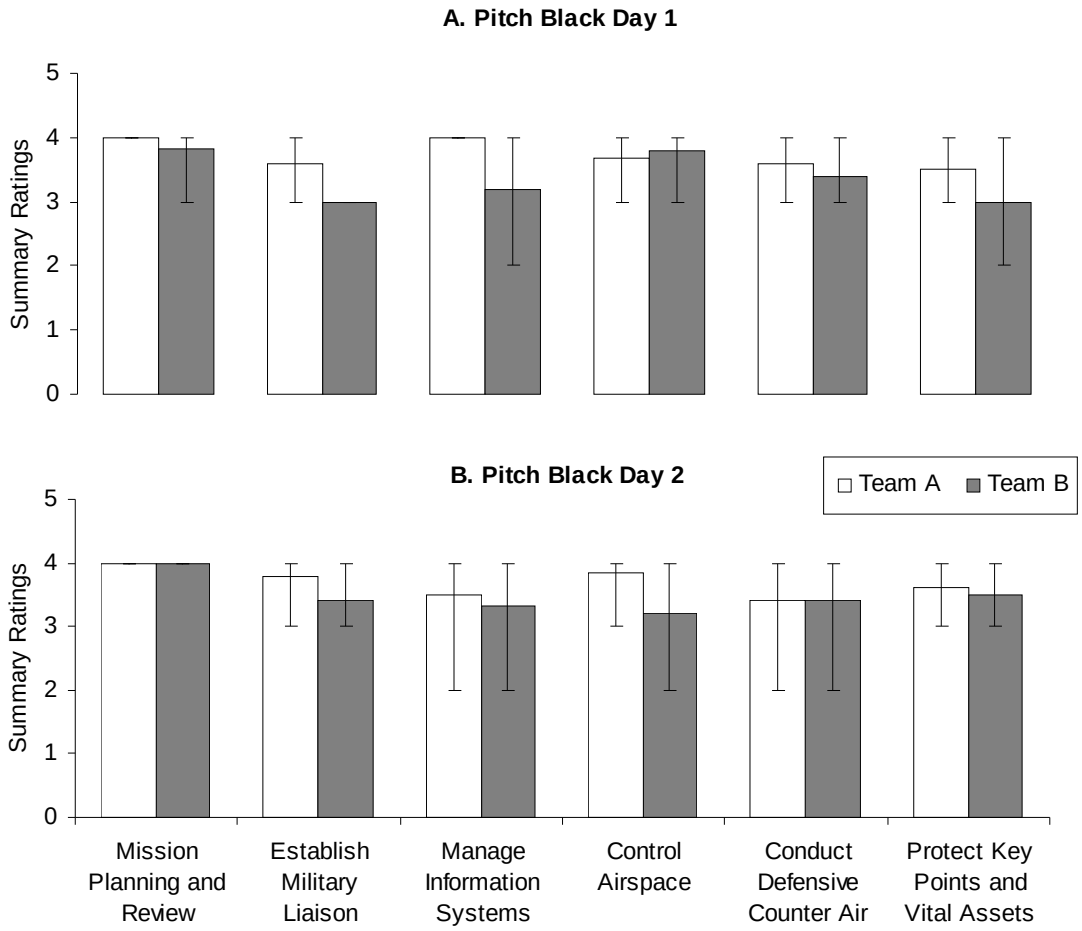

Figure 7: Summary ratings on the principal dimensions of taskwork performance of the team that received the virtual preparation (Team A) and the control team (Team B) for Day 1 (Panel A) and Day 2 (Panel B) of PB08. Error bars show the range of component performance ratings. For dimensions where no error bars are displayed all component ratings were the same

3.3.2 Quantitative and Qualitative Evaluation of Teamwork Processes during Pitch Black 08

As illustrated in Figure 8, the team that received the virtual preparation was rated by the SACTU assessor as clearly superior to the control team across all the dimensions of teamwork: information management, communication, supporting behaviour, and initiative and leadership.

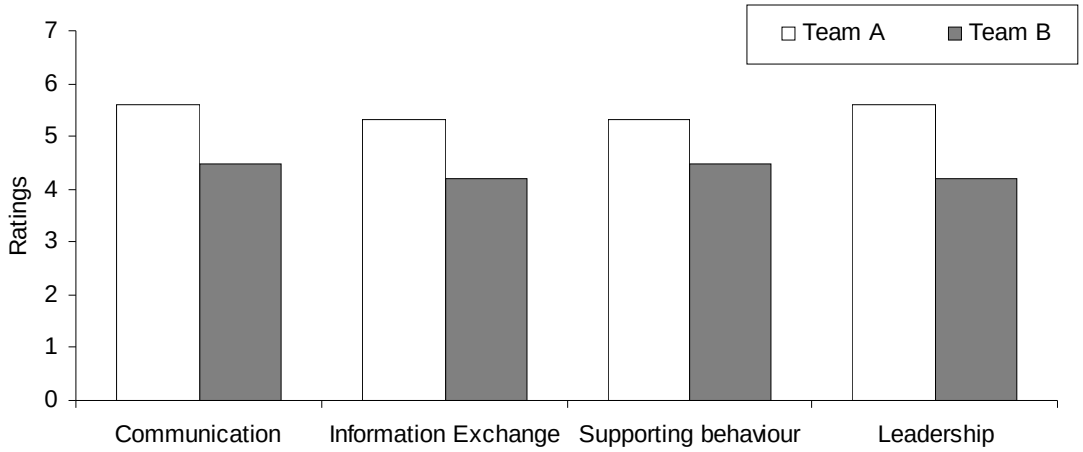

Figure 8: Assessor ratings of team processes for the team that received the virtual mission preparation and the control team on Day 1 of Exercise Pitch Black 08

The assessor noted that although there was actually a higher frequency of communication in the control team, this communication was less efficient. For example, in the control team, communication between the fighter controllers usually passed through the Tactical Director; in the Black Skies team, the fighter controllers communicated directly, resulting in both a faster transmission of information and a significantly lower workload for the Tactical Director. This pattern of communication is indicative of a greater level of trust within the ABM team that received the virtual mission preparation, and greater initiative on the part of the Fighter Controllers.

Overall, the assessor reported that there was a greater degree of implicit coordination within the Black Skies team: they were more likely to provide information to team members when they needed it and before they had to ask for it. They also spent less time discussing the team's tactics during mission execution and instead simply implemented previously-discussed plans. This suggests a greater familiarity with each other's roles, responsibilities, and abilities.

3.4 The Benefit to the RAAF from the Virtual Mission Preparation

Kirkpatrick's final training evaluation criteria is concerned with the ultimate value of the training program to the organisation (Muchinsky, 1993). This is a notoriously difficult criterion to evaluate. While no formal utility analysis was undertaken as part of this study, the virtual mission preparation provided in Black Skies 08 had obvious practical benefits for both organisational and operational elements within Pitch Black 08. These benefits centred around maximising the training benefits of an extremely costly and resource-intensive event such as Pitch Black 08.

First, the White Force elements responsible for developing and implementing the Pitch Black 08 missions benefited considerably from their involvement in Black Skies 08, as the virtual mission preparation served to highlight deficiencies in the scenarios that were planned for the

subsequent live exercise. For example, it became apparent during Black Skies 08 that aspects of the scenario were likely to increase the possibility of breakdowns in aircraft separation in a particular region of airspace. This situation arose because the sensor and communications coverage in that region of airspace was degraded due to distance; this had the consequence of reducing the effective area of situational awareness and influence of the ABM team. This vignette was subsequently amended for Pitch Black 08, reducing the risk of a safety incident during the live exercise.

Second, the ABM team that attended Black Skies 08 benefited from the virtual mission preparation in that they were able to more effectively utilise the valuable training opportunity presented by Pitch Black 08. According to this team, the training benefits of the first few days of any large-scale, multi-national exercise are usually lost in the process of familiarising themselves with the sheer volume of Red and Blue aircraft, identifying the most effective role configuration within the team, and refining coordination strategies, procedures, and tactics. It is worth pointing out that during the first two days of Pitch Black 08, there were roughly one hundred aircraft airborne for more than ten hours. The ABM team that received the virtual mission preparation reported that, save for the virtual mission preparation, this initial period would have offered very little training benefit. It is also possible that the enhanced preparedness of this team also had flow-on benefits for the training experience of other participants in Pitch Black 08.

4. Discussion

The principal aim of this study was to investigate the benefits of using a synthetic environment to provide mission preparation for a command and control team prior to a live warfighting exercise. Our specific research questions were couched within Kirkpatrick's (1959) framework for the evaluation of training programs: Reaction, Learning, Behavioural, and Results.

In respect to participants' reactions to the virtual mission preparation, the members of the ABM team that participated in Black Skies 08 reported that the exercise had considerable combat mission training value: they felt it had a positive impact on their team coordination, their tactical skills, and their overall combat mission readiness. Significantly, they believed that it provided a learning experience not available in their regular program of training. In fact, the ABM team reported that Black Skies 08 compared favourably to both regular training *and* live exercises such as Pitch Black 08 in terms of the capacity to provide training experiences critical to the ABM role. The synthetic environment was viewed as inferior to the live environment primarily in its capacity to provide training in interacting with a significant number of other command elements and external agencies.

In terms of the extent to which Black Skies 08 served as an effective learning experience, the ABM team that participated in the virtual mission preparation demonstrated a marked improvement in teamwork processes, and reported an increase in collective self-efficacy and cohesion, over the course of the exercise. They also showed a clear improvement across most, but not all, of their mission essential tasks. The tasks that showed the most improvement

included those associated with the control of airspace and establishing military liaison; the tasks that showed the least improvement included core DCA tasks such as the prioritisation of threats and intercept geometry (the discrepancy between the reaction-level findings and these learning-level findings is discussed below).

In relation to Kirkpatrick's behavioural-level criteria, the ABM team that participated in Black Skies 08 performed better overall than the control team during the subsequent live warfighting exercise. This performance advantage was most evident in terms of superior teamwork processes, although the team that received the virtual mission preparation also performed better across most mission essential tasks on the first day of Pitch Black 08. On the second day of the live exercise, the gap in taskwork performance between the two teams was not as great.

Finally, to the extent that it was possible to evaluate Kirkpatrick's (1959) Results criteria in the timeframe of this study, Black Skies 08 also demonstrated a broader organisational and operational value to the RAAF: it provided the White Force with the opportunity to identify deficiencies in, and mitigate risks associated with, the Pitch Black 08 mission scenarios; it allowed the ABM team to refine their Pitch Black 08 plans and procedures, enabling them to more effectively utilise the valuable training opportunity presented by a large-scale, live warfighting exercise.

These findings are consistent with previous research into the use of synthetic environments to provide team and collective training for air operations, the bulk of which suggests that it draws favourable reactions from participants (McIntyre et al., 2002; Schreiber et al., 2006; Smith et al., 2006) and has a positive impact on team processes and taskwork skills (McIntyre et al., 2002; Schiflett et al., 2000; but see Smith & McIntyre, 2003). The current study makes a novel and significant contribution to this research by also demonstrating that a command and control team that received virtual mission preparation for a live warfighting exercise performed better than a team that did not receive this training.

Broadly speaking, these findings suggest that providing team training in a synthetic environment holds significant potential for the RAAF. These technologies and methods provide teams of warfighters with the opportunity to link together to engage in high-level training and mission rehearsal, and to experiment with new tactics and capabilities, more frequently – and in a more cost-effective manner – than is possible using real platforms. Conducting activities of this kind on a more frequent basis offers the potential to enhance operational readiness through training, and to accelerate improvements in organisational processes through experimentation.

4.1 Limitations of this Study and Future Research and Development

4.1.1 Discrepancy between Reaction-Level and Learning-Level Outcomes

In this study there were some contradictory findings which require further discussion. Although the virtual mission preparation resulted in improved performance on most mission essential tasks over the course of Black Skies 08 and subsequently during Pitch Black 08, it had little impact on a subset of tasks directly concerned with the conduct of DCA missions; these

tasks included the effective employment of forces and the management of rules of engagement. This finding is surprising given that the ABM team that received the virtual mission preparation reported that Black Skies 08 provided a more valuable training experience for these core defensive counter air tasks than for any other category of mission essential tasks. At a broader level, this inconsistency between reaction-level results and learning-level results highlights both the limitations of relying on reaction-level data to draw conclusions about the effectiveness of a training program (Tannenbaum & Yukl, 1992), and the benefits of evaluating the effectiveness of training programs at different levels (Kirkpatrick, 1959) or on different dimensions (Kraiger, 2003).

There are a number of possible explanations as to why no benefit was observed on this training objective over the course of the study. First, it is possible that the measure we employed was not sensitive to variability in the performance of DCA tasks during Black Skies 08 and Pitch Black 08 (i.e., the measure was not sufficiently valid). Second, the scenarios in Black Skies 08 and Pitch Black 08 may not have been sufficiently complex or demanding to elicit a superior demonstration of DCA skills from either ABM team (although this explanation would also run counter to reaction-level findings). Third, it is possible that Fighter Controllers are so well practiced in this aspect of their role that the few days of training provided in Black Skies 08 had no appreciable impact on their performance at a team level. This interpretation is consistent with previous research showing a lack of improvement in role-specific skills over the course of synthetic training exercises (Best et al., 2007; Smith & McIntyre, 2003).

It would not be wise to conclude from one case study, and against the general trend of results, that these particular DCA skills can not be trained in a synthetic environment. This finding does, however, serve to highlight the point raised by Smith and McIntyre (2003): the use of networked simulators will not, in and of itself, guarantee the learning of critical skills or improvements in performance. Further work is required to fully understand the factors that determine the effectiveness of such training.

4.1.2 Future Research and Development

This study has in fact generated several avenues for further research, both specific and broad. The findings that have emerged from this study suggest three specific areas in which further work is warranted. As intimated above, one of the principal goals will be to identify the locus of the discrepancy we observed between reaction-level findings and learning-level findings in relation to core DCA tasks. A second goal is to examine the extent to which the performance benefits associated with participating in virtual mission preparation decay over time: in the current study, we were able to assess the performance of ABM Teams only on the first two days of the Pitch Black 08; in future studies we hope to evaluate the impact of virtual mission preparation on subsequent performance over the duration of a live warfighting exercise. A third goal is to extend the generalisability of our findings by examining the impact that virtual mission preparation has on other command and control teams, as well as warfighting teams more generally (such as the aircrew, Joint Terminal Attack Controller, and other elements that make up a close air support team).

More broadly, the findings of this study – and the findings of the body of work on which it builds – suggests that there are many aspects of team and collective training in synthetic environments which require further research. These include (1) the integration of live, virtual, and constructive systems; (2) the development of tools to facilitate collaboration during distributed mission planning and debriefing; (3) the development and evaluation of more efficient methods for the creation and management of training content; (4) valid and reliable measurement of team and collective performance; and (5) methods of providing rapid and detailed after action review.

In order to more efficiently address these and other research questions, DSTO is proposing to take part in a collaborative program of research involving DSTL in the UK, the Canadian Forces Experimentation Center, the Defence Technology Agency in New Zealand, and laboratories within the US Air Force, Navy, and Army. This program of research will not only allow the RAAF (and the ADF more broadly) to leverage the substantial investments in synthetic training capabilities that have already been made by our principal allies, but it will serve to enhance future interoperability with the forces of the participating nations.

4.2 Conclusion and Implications for RAAF Synthetic Training Capability

Decision superiority – the ability to make and implement more informed and more accurate decisions at a rate faster than the enemy – is at the heart of future RAAF capability (Air Power Development Centre, 2007). The ability of the RAAF to achieve and maintain decision superiority will depend on the professional mastery of its warfighters; this professional mastery will in turn depend on the extent to which they have the opportunity to undertake high-level training, mission rehearsal, and experimentation on a regular basis. Given its resource constraints, the RAAF has identified virtual and simulated environments as crucial to providing the opportunity for its warfighters to develop professional mastery. The outcomes from this study are significant in that they provide initial support for the previously untested doctrine that training in a synthetic environment can have a significant impact on the ability of RAAF command and control teams to perform their mission in large-scale, complex, and dynamic warfighting situations.

On the basis of the outcomes of this study, and the US and UK research on which this study builds, we are in a position to make five key recommendations concerning the synthetic training capability of the RAAF. The recommendations are displayed in Table 2 (overleaf), and discussed further below.

Table 2: Recommendations for RAAF synthetic training capability

	Recommendations for RAAF Synthetic Training Capability
1	RAAF should expand its capacity to provide synthetic team and collective training for its warfighters
2	RAAF should support further research into the effective and efficient use of synthetic team and collective training technology
3	RAAF (and the ADF more broadly) should invest in dedicated infrastructure for synthetic team, collective, and joint training
4	RAAF should utilise DSTO's research experience to guide further investment in, and application of, tools and method for synthetic team and collective training.
5	RAAF should expand its participation in coalition synthetic training exercises, and facilitate the conduct of collaborative research and development with coalition partners

The principal recommendation is that the RAAF should expand its capacity to provide synthetic team and collective training for its warfighters. This recommendation, however, comes with two significant caveats and associated recommendations. The first caveat is that, as outlined earlier in the discussion, further research is required into factors that influence the effectiveness and efficiency of team and collective training in synthetic environments, in order to ensure that the benefit of such training is maximised. The second caveat is that the utility of simulation assets is constrained by their method of employment and by their accessibility. Recognising this fundamental constraint, other nations have developed dedicated mission training and experimentation facilities – such as the Distributed Mission Operations Centre in the US, and the Air Battlespace Training Centre in the UK – that are distinct from the infrastructure used for purposes such as procedures training. It is unlikely that the RAAF's existing simulation assets are sufficient to realise the full potential for team and collective training offered by synthetic environments. We therefore recommend that the RAAF (and the ADF more broadly) develop dedicated infrastructure for this purpose, and that RAAF utilise DSTO's research experience to guide both this investment and the subsequent application of the synthetic training capability. Finally, we recommend that the RAAF seize the opportunity to benefit from the significant investment that our principal allies have already made in collective and joint training in synthetic environments. The RAAF can do so by increasing its level of participation in coalition synthetic training exercises, and by supporting and facilitating the conduct of collaborative research and development between DSTO and the laboratories of partner nations.

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Appendix A: Descriptive Statistics from Trainee Reactions Questionnaire Items

Table A1: Mean Ratings of Agreement with Items in the Fighter Controller Reactions Survey

Categories and Items	*M*	*SD*
Overall Utility and Potential Applications of Virtual Mission Preparation		
This experience has motivated me to seek similar training opportunities	6.00	0.00
Participating in EBS was a good use of my time	6.25	0.96
I would recommend this experience to other controllers	6.75	0.50
Exercise like EBS should be part of our readiness training schedule	6.50	0.58
I would like to see MTDS operational applications expanded	4.75	1.89
Exercises like EBS should be a part of all future spin-up exercises	6.75	0.50
MTDS has considerable combat mission training value	5.75	1.50
EBS has limited military training value	2.00	0.82
Impact of Virtual Mission Preparation on Mission Skills and Readiness		
This exercise has positively impacted my combat mission readiness	6.50	0.58
MTDS has improved my combat mission readiness	5.50	0.58
I am confident I will perform better as a controller as a result of MTDS	6.25	0.96
The material I learned in MTDS is useful for my future controller experience	5.00	2.00
As a result of this training, I have improved my mission planning skills	3.75	1.26
I have improved my tactical skills as a result of the MTDS experience	5.50	1.29
MTDS improved my understanding of critical combat skills	4.75	0.96
I improved my briefing and debriefing skills	3.75	1.26
I feel I will be better prepared to brief and lead a mission due to this exercise	6.25	0.50
EBS has helped me improve my team coordination skills	6.00	1.15
This exercise helped me improve my combat situational awareness	5.50	0.58
Specific Training Opportunities Provided by Virtual Mission Preparation		
EBS provided an excellent opportunity to interact with people/systems I will interact with in actual combat	6.50	1.00
EBS offered an excellent opportunity to experience multiple complex presentations	5.75	1.26
EBS provided valuable experience in large force training	6.25	0.96
This training provided excellent experience in radar mechanics	3.25	0.96
This exercise provided excellent practice on my communication standards	5.75	0.50
MTDS provides valuable experience in combat mission tactics	5.00	1.41
EBS provided an excellent opportunity for me to practice my control skills	6.50	1.00
EBS provided an excellent opportunity for me to practice my team coordination skills	6.50	0.58
EBS provided a limited opportunity to train my combat skills	3.25	2.06

Categories and Items	*M*	*SD*
Relation Between Virtual Mission Preparation and Regular Training		
I can routinely get the type of experience I had in MTDS at my home unit	2.75	1.50
At my unit, I routinely get to control aircraft against realistic threats	4.25	2.22
I can routinely get training similar to that provided in EBS at home unit	1.75	0.50
I routinely get to practice tactics in multiple aircraft environments at my operational unit	4.50	1.73
I will have an opportunity to use what I've learned in EBS at my operational unit	6.75	0.50
My home unit's daily OPSTEMPO will help me maintain the skills I have learned in EBS	3.50	1.73
Fidelity of the Virtual Mission Preparation		
The controller console was realistic	6.75	0.50
The missions were realistic	5.25	1.50
The exercise environment was a realistic representation of combat	4.00	1.83
MTDS provides realistic training and experience	5.50	1.29
MTDS missions and engagements accurately represent how things happen in the operational world	3.75	1.50
Generally, the fidelity of the MTDS environment is sufficient to achieve the desired mission / training objectives	5.75	0.50
The threats in this exercise behaved as they do in the operational environment	4.75	1.89
The EBS missions I experienced were unrealistic	2.75	0.96
The skills I trained in EBS are the same as those I am expected to perform in the field	6.00	0.82
Training Design and Procedure		
The learning objectives were presented clearly	5.25	1.71
The missions helped me to effectively meet my learning objectives	6.25	0.96
In training, I was able to apply lessons learned from previous missions to new ones	6.00	0.82
The scenarios were well-designed	5.75	0.50
I felt the flow of EBS was appropriately paced	4.25	2.22
It was difficult to keep up with the pace of the missions	2.00	0.82
The missions were challenging	5.75	0.96
The missions and engagements were very challenging	5.25	1.71

Note: The general term Mission Training via Distributed Simulation (MTDS) is used in these items to refer to the kind of training experience provided by Black Skies 08.

Table A2: Mean ratings of the extent to which it is possible to provide critical ABM team experiences in the virtual exercise, live exercise, and home unit training environments

Air Battle Management Team Experience	Training Environment					
	Virtual exercises		Live exercises		Training at home unit	
	M	*SD*	*M*	*SD*	*M*	*SD*
Liason / briefer in a contingency operation or exercise	1.50	0.58	2.75	1.26	2.00	1.41
Various ROE	3.50	1.00	3.25	0.96	2.75	1.50
Operations near neutral airspace	3.00	0.82	2.75	0.96	1.75	0.96
Airspace restrictions	3.75	0.50	3.50	0.58	2.75	0.96
Joint operations - planning	2.25	1.26	3.00	1.15	1.25	0.50
Joint operations - integrating, communicating, identifying	1.75	1.71	2.75	0.96	1.25	0.50
Combined operations - planning	1.75	1.71	3.25	0.96	1.50	0.58
Combined operations - integrating, communicating, identifying	1.75	1.71	3.00	1.15	1.50	0.58
Face to face mission planning	1.25	0.96	2.25	2.06	2.50	1.29
Mission documentation / reconstruction / intel debrief	2.00	1.63	2.25	1.50	1.75	0.50
Working in a mission planning team	2.00	1.83	2.25	2.06	1.00	0.82
External coordination with ATC or airspace owner	1.00	0.82	3.25	0.96	3.50	0.58
Working with electronic warfare assets on VPN	1.25	1.26	2.75	1.50	0.50	0.58
Working with electronic attack assets	1.75	1.50	2.50	1.73	0.25	0.50
Coordinate through links with other interface units	1.75	1.71	2.50	1.73	0.50	1.00
Force marshalling / Battle management	3.50	0.58	3.75	0.50	2.75	0.96
Working with various ground parties	2.00	1.41	2.50	1.73	0.50	0.58
Coordination with other C2ISR players	2.00	1.41	2.75	1.50	1.00	0.82
Working in a radar / IFF jamming environment	2.50	1.91	2.25	1.26	0.75	0.96
Working in a communications jamming environment	2.50	1.91	2.50	1.29	1.00	1.15
Working in a dense emitter environment	2.75	1.89	2.50	1.00	1.25	0.50
Detecting different types of targets	3.50	0.58	2.50	1.29	2.00	1.63
Various geography	3.25	0.96	2.75	0.96	1.75	0.96
Various environments	2.25	2.06	2.75	0.96	2.50	1.29
Identifying various types of entities	2.00	1.83	2.25	0.96	1.25	1.50
Close control stem VID	3.25	0.96	1.25	1.26	1.75	0.96
Detecting, ID, comm., tracking, prosecuting a HFF	3.50	0.58	3.50	1.00	1.75	0.50
Apply ID matrix	3.50	1.00	3.50	1.00	3.50	0.58
Strangers / unknowns in the airspace including normal ATC traffic	3.50	0.58	1.25	0.50	1.75	0.96
Working with a degraded picture	3.75	0.50	2.50	1.00	2.00	1.41
Describing non standard group formations	3.25	1.50	3.75	0.50	2.75	0.50
Red air tracking 6 or more groups	3.75	0.50	2.75	0.96	0.75	0.50
Blue air tracking 6 or more groups	3.75	0.50	3.00	1.15	1.00	0.82
Update track info	2.75	0.96	2.75	0.96	2.50	1.00
A variety of enemy threats and tactics	3.75	0.50	2.75	0.96	1.25	0.50
A variety of friendly capabilities and tactics	3.00	1.41	3.00	1.41	1.25	0.50

Air Battle Management Team Experience	Training Environment					
	Virtual exercises		Live exercises		Training at home unit	
	M	*SD*	*M*	*SD*	*M*	*SD*
Tracking radar only and / or mode 4 only	3.25	0.50	1.75	0.96	1.00	0.82
Degraded comm.	2.75	1.50	2.50	0.58	1.25	1.26
Dense internal and external comm environment	2.75	1.50	2.75	0.50	1.50	0.58
Dense and / or complex link environment	2.25	2.06	1.00	1.15	0.25	0.50
Working with HAVE QUICK comm.	2.00	1.63	2.50	1.29	1.75	1.26
Working with secure comm.	2.00	1.63	2.25	0.96	1.25	0.50
Maintain safe control 6 or more groups	3.50	0.58	2.25	0.50	1.00	0.82
Air refueling	3.50	0.58	3.00	0.82	0.75	0.50
WD directed air refueling	2.25	1.71	2.25	0.50	0.75	0.96
Tanker management	3.25	0.96	2.50	0.58	0.75	0.96
AOC coordination	2.75	1.50	3.00	0.82	0.50	0.58
Dynamic ground and air enemy order of battle	3.25	0.96	3.00	0.82	1.00	0.00
Working as check-in controller	3.25	0.50	3.75	0.50	1.50	1.00
Controlling a large strike package	3.75	0.50	2.75	1.50	0.25	0.50
Rapidly changing targets and priorities	3.25	0.50	2.75	0.96	1.25	0.96
Position E-3 orbit	3.25	0.96	2.25	0.50	0.25	0.50
Emergency procedures on board and off board	3.50	0.58	1.75	1.71	2.00	1.83
Keeping track of flight and time on target deconfliction	3.00	0.82	3.50	0.58	1.75	0.96
HVAA protection	3.50	0.58	3.00	0.82	1.00	0.00
Working with CSAR assets / working with Hook 112	2.00	0.82	2.50	1.29	0.50	0.58
Multiple contingency / fragged missions	3.25	0.96	2.25	0.50	0.25	0.50
Working a split frequency war	3.50	0.58	3.00	0.82	0.75	0.50
Leaker scenario	3.50	0.58	3.50	0.58	1.75	0.96
Return to force procedures / lame duck procedures / safe passage	3.25	0.96	2.50	1.29	0.25	0.50
Station handover	3.00	1.15	2.50	1.00	1.75	1.71
Troubleshooting primary and secondary sensors	3.25	0.96	3.00	1.41	2.75	1.50
Hands-on platform familiarisation	1.50	1.73	2.25	0.96	1.25	1.50
Procedural control	3.25	0.50	2.75	0.96	0.75	0.50
Dynamic ACMs	3.75	0.50	3.25	0.50	1.00	0.82
Joint fire	3.50	0.58	3.25	0.50	1.00	0.82

DEFENCE SCIENCE AND TECHNOLOGY ORGANISATION
DOCUMENT CONTROL DATA

1. PRIVACY MARKING/CAVEAT (OF DOCUMENT)

2. TITLE

Exercise Black Skies 2008: Enhancing Live Training Through Virtual Preparation□□Part One: An Evaluation of Training Effectiveness

3. SECURITY CLASSIFICATION (FOR UNCLASSIFIED REPORTS THAT ARE LIMITED RELEASE USE (L) NEXT TO DOCUMENT CLASSIFICATION)

Document	(U)
Title	(U)
Abstract	(U)

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6a. DSTO NUMBER	6b. AR NUMBER	6c. TYPE OF REPORT	7. DOCUMENT DATE
DSTO-RR-0344	AR-014-567	Research Report	November 2009

8. FILE NUMBER	9. TASK NUMBER	10. TASK SPONSOR	11. NO. OF PAGES	12. NO. OF REFERENCES
2009/1033209	AIR 07/232	Deputy Chief of Air Force	36	33

13. URL on the World Wide Web

http://www.dsto.defence.gov.au/corporate/reports/DSTO-RR-0344.pdf

14. RELEASE AUTHORITY

Chief, Air Operations Division

15. SECONDARY RELEASE STATEMENT OF THIS DOCUMENT

Approved for public release

OVERSEAS ENQUIRIES OUTSIDE STATED LIMITATIONS SHOULD BE REFERRED THROUGH DOCUMENT EXCHANGE, PO BOX 1500, EDINBURGH, SA 5111

16. DELIBERATE ANNOUNCEMENT

No Limitations

17. CITATION IN OTHER DOCUMENTS Yes

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Team performance, command and control, training, simulation, air warfare, readiness

19. ABSTRACT

This research employed a case study strategy to examine the benefits of using synthetic environments to provide mission preparation for command and control teams prior to a large-scale, live warfighting exercise. During Pitch Black 08, we compared the performance of two Air Battle Management (ABM) teams from 41 Wing, Surveillance and Response Group: one team prepared by supporting normal flying operations, the other took part in a virtual mission preparation exercise named Black Skies 08. The synthetic environment provided in Black Skies 08 was designed to simulate Pitch Black 08 as closely as possible in terms of mission scenarios, order of battle, airspace, procedures, and tactics. The evaluation of the training provided in the virtual mission preparation was carried out using the four-level model developed by Kirkpatrick (1959): Reaction, Learning, Behavioural, and Results critera. The members of the ABM team that participated in Black Skies 08 reported that the virtual mission preparation compared favourably to both regular training and live exercises in terms of the capacity to provide training experiences critical to the ABM role. Over the course of the virtual mission preparation, the ABM team displayed a marked improvement in teamwork processes, motivational state, and across most mission essential tasks. During the subsequent live warfighting exercise, the teamwork processes and taskwork performance of this team were rated as better overall than those of the matched ABM team that did not take part in virtual mission preparation. The virtual mission preparation also demonstrated a broader organisational and operational value to the RAAF: it provided the White Force with the opportunity to identify deficiencies in, and mitigate risks associated with, the Pitch Black mission scenarios; and it allowed the ABM team to refine their Pitch Black plans and procedures, enabling them to more effectively utilise the valuable training opportunity presented by a large-scale, live warfighting exercise.